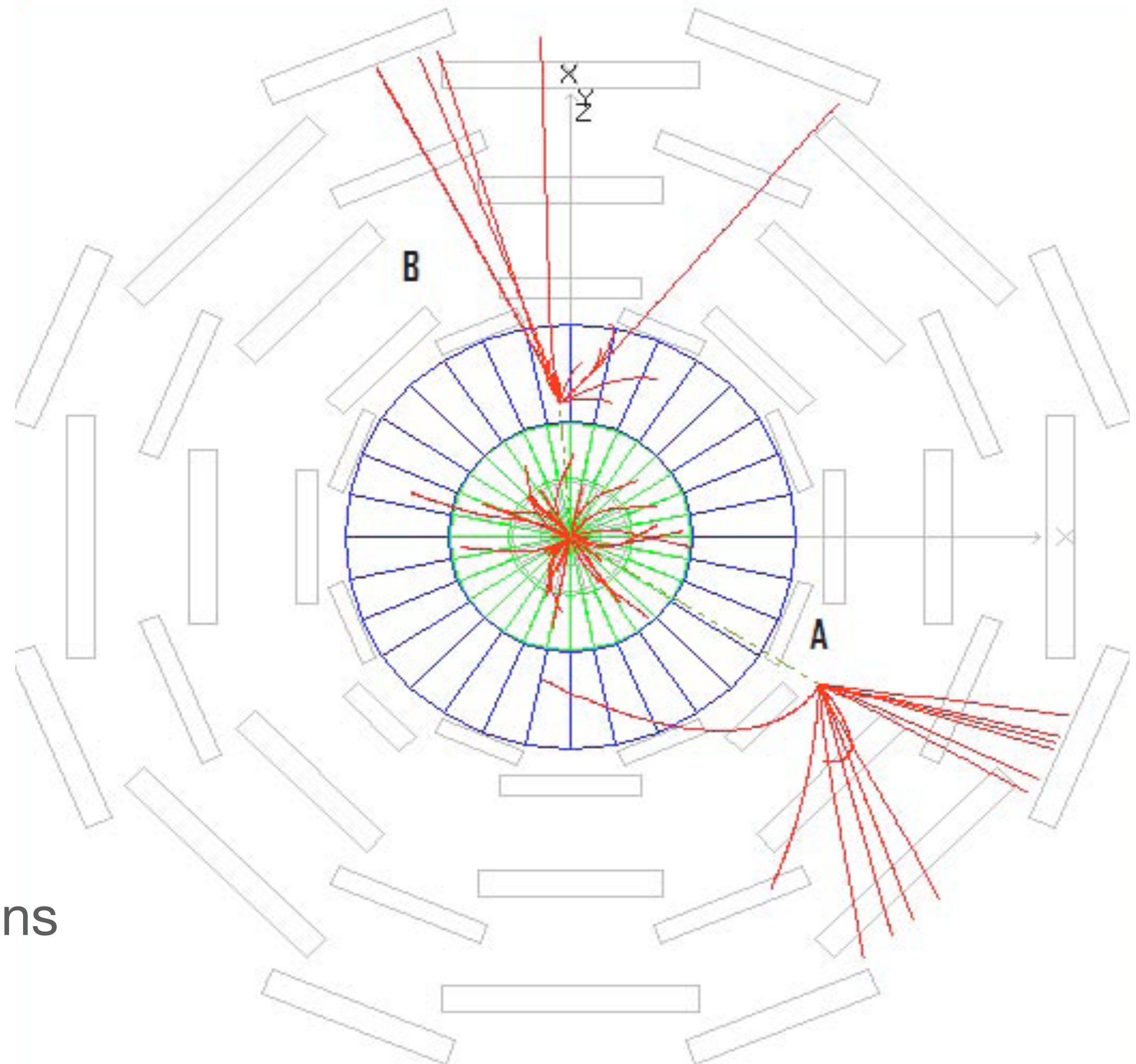
Search for Long Lived Particles in ATLAS and CMS



Stefano Giagu
Università di Roma and INFN Roma
For the ATLAS and CMS Collaborations

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Motivation & Outline

- Direct search of new physics effects from striking signatures at the LHC:
  - low-velocity massive charged particles with high p_T
  - long lived neutral particles decaying in heavy-flavor jets
- Ideal candidates for an early discovery
  - can be observed with low integrated luminosity at beginning of data taking
- Experimental issues resulting from the “non conventional” signatures
  - special attention to trigger and detector operation is crucial

Outline

- Meta-stable heavy charged particles:
  - charged: stau
  - charged and coloured: gluino, stop
- Long lived neutral particles:
  - Hidden Valley particles

Related talk at this conference:
M.Chiorboli - Prospects for non-standard SUSY searches at LHC - SUSY session

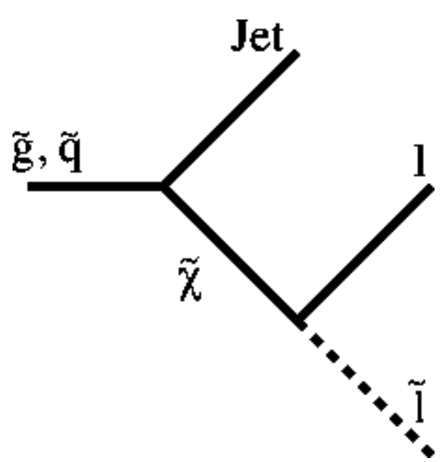
Meta-stable s-leptons and R-hadrons

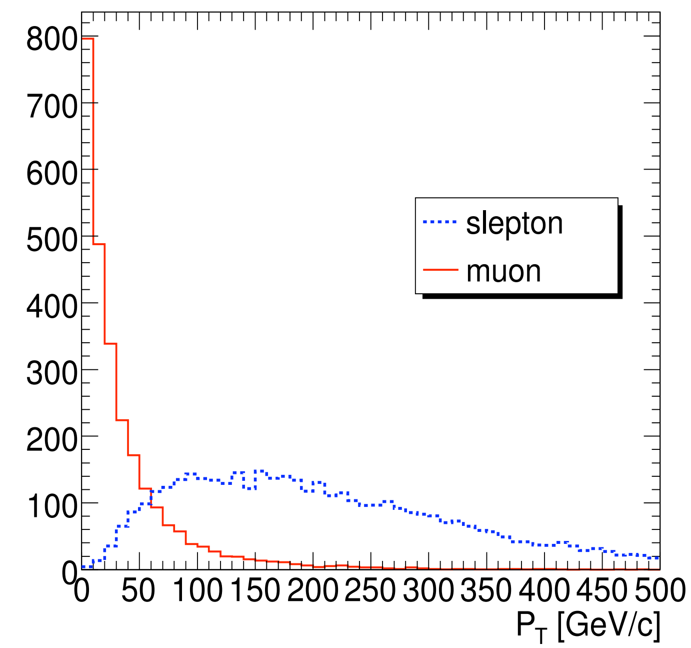
- Predicted by many BSM models: GMSB, Split-SUSY, Extra-Dimensions, mSUGRA ...
- Common signature largely model independent:
  - heavy slow charged particles with high transverse momentum: large dE/dx, long TOF

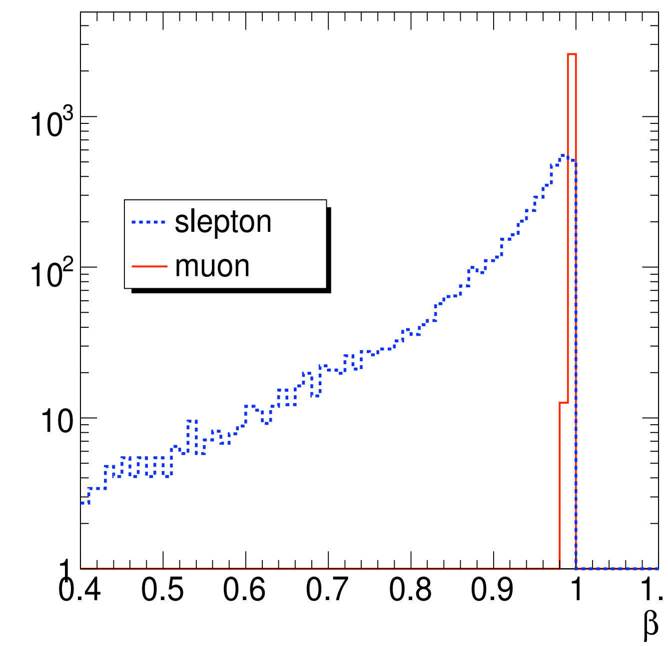
Example model: GMSB

co-NSLP: stau, selectron

- x-sections ~O(10) pb
- cascade decay
- NLSP can be very long lived



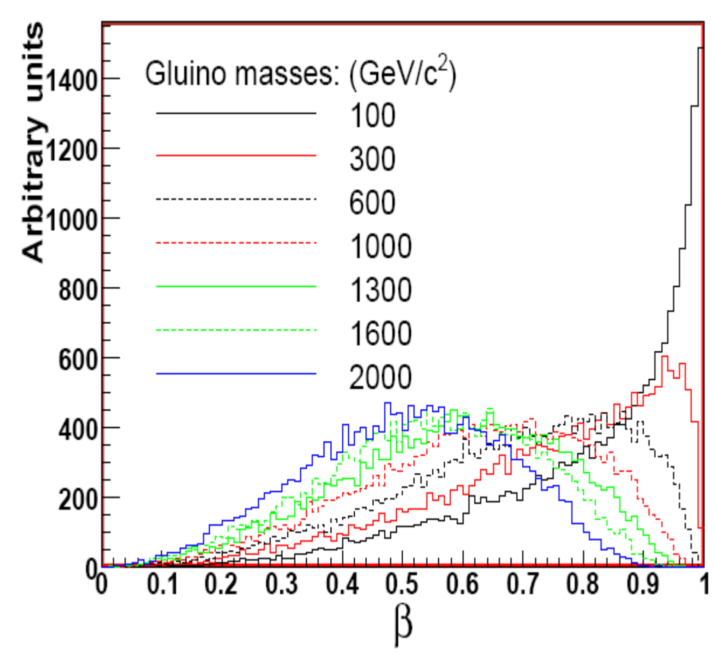




Example model: Split-SUSY

NLSP: gluino

- x-sections $10^{-3} \div 10^{3}$ pb
- direct production: $gg \rightarrow \tilde{g}\tilde{g}$
- hadronize to long-lived R-hadrons ($\tilde{g}q\bar{q}$, $\tilde{g}qqq$, $\tilde{g}g$)
- do not shower in calorimeters



Best Mass limits

$M_{\tilde{l}} > 90 \div 105$ GeV (CDF/LEP)

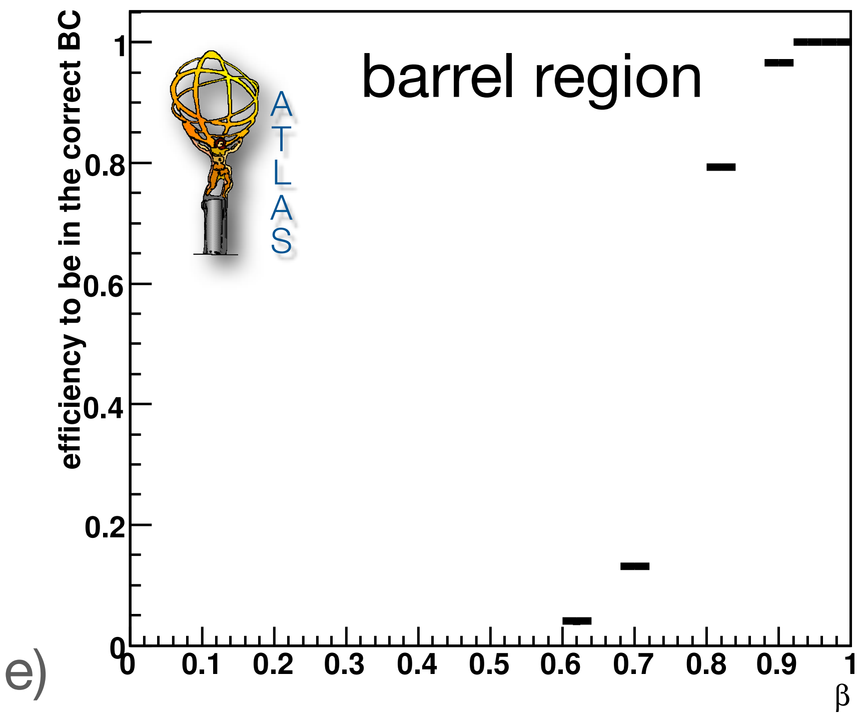
$M_{\tilde{g}} > 170\text{-}300$ GeV (CDF)

Detection issues

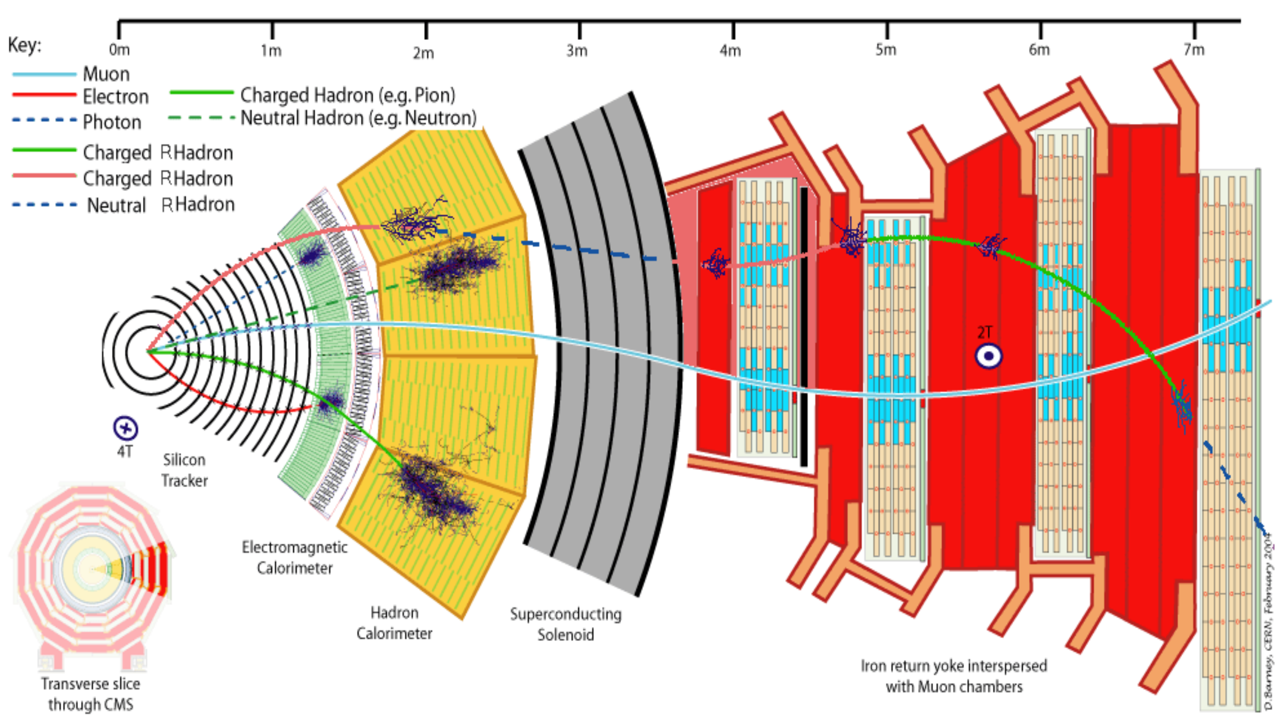
- Muon-like signature but:
  - due to particle slowness, trigger and data acquisition efficiency may be affected:

if β<<1 the event may be associated with the wrong bunch crossing

Efficiency in the correct bunch-crossing



- R-hadrons most demanding case
  - direct pair production → must relies on the two R-hadrons only
  - both particles can be slow
  - charge flipping (trajectory modified and neutral R-hadrons not visible)

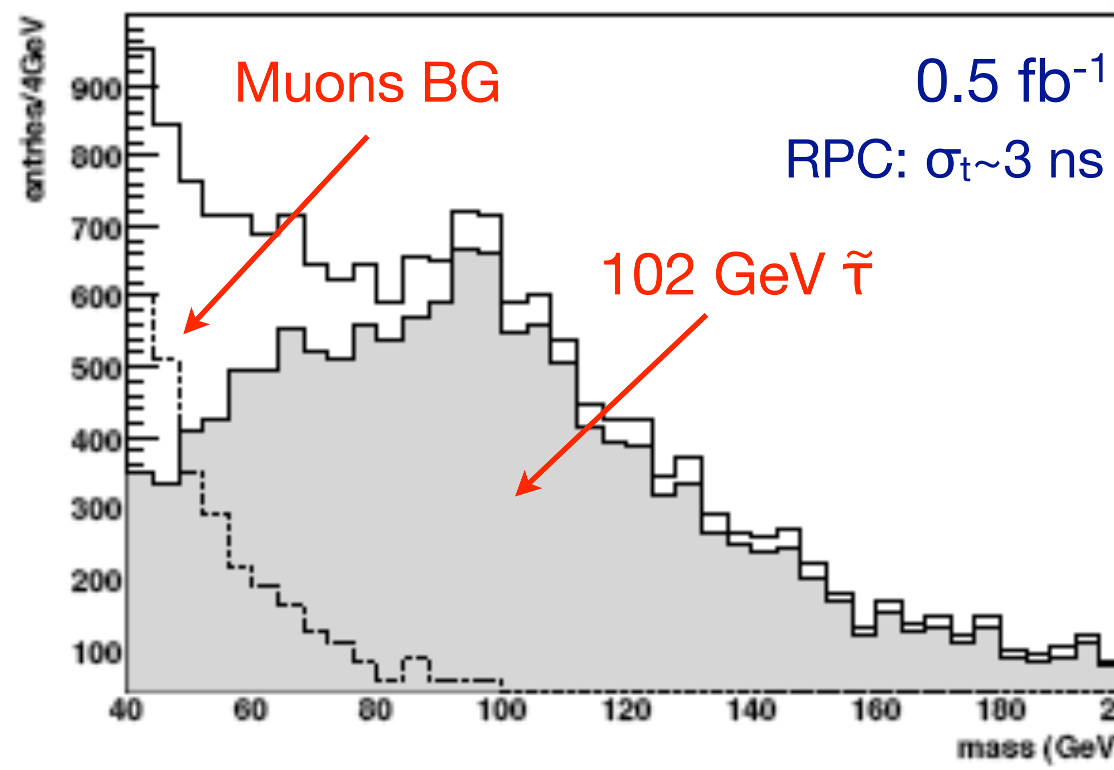


	HLT Trigger Path Efficiencies [%]				
	MU	MET	$\sum E_T$	JET	Total
$\tilde{\tau}$ 150-250 GeV	~97	~80	~90	~70	>99
$\tilde{g}$ 200-1500 GeV	~15	~30-60	~40-95	~10-50	~60-95
$\tilde{t}$ 130-800 GeV	~20	~20-40	~20-60	~4-20	~40-70

Velocity and Mass measurements

$$m = p\sqrt{\frac{1}{\beta^2} - 1}$$

Reconstructed Mass at Level-2

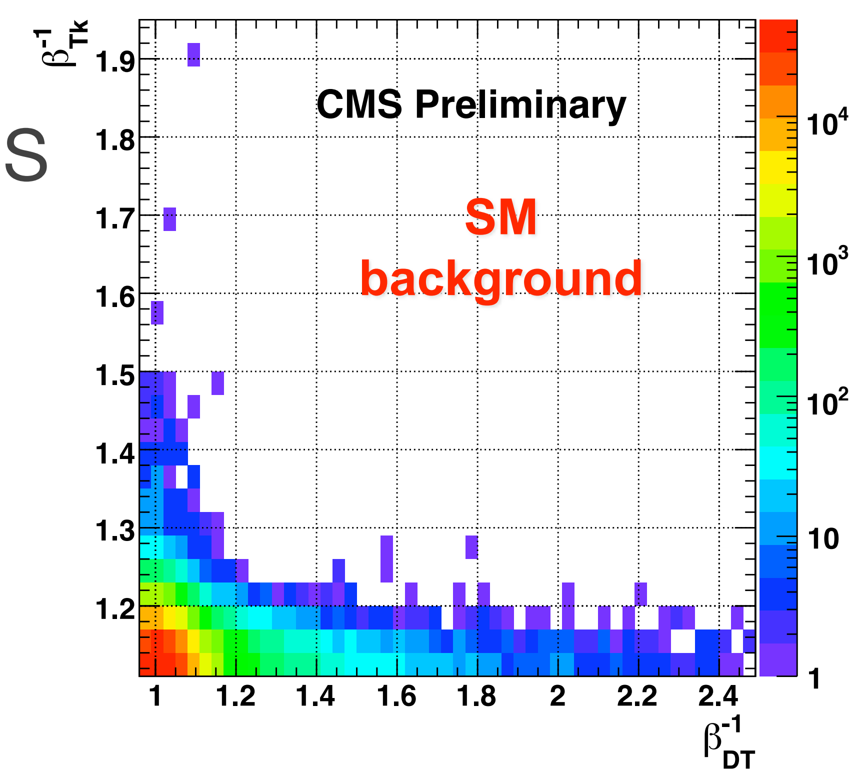


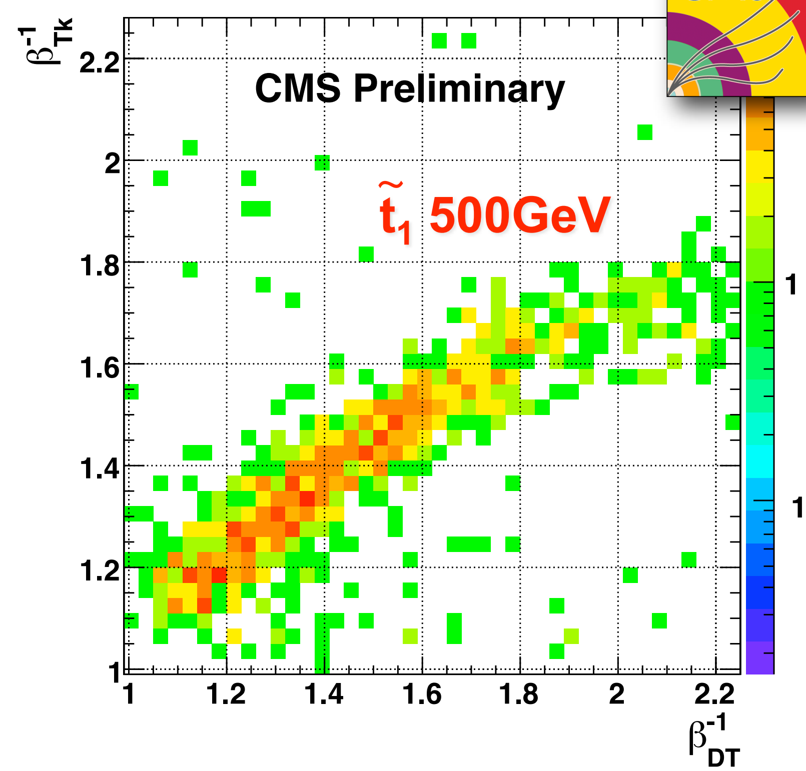
- β from time-of-flight: ATLAS/CMS
  - uses muon detectors timing information to extract delays with respect to β=1 particles

- β from specific ionization: CMS
  - dE/dx measured in silicon tracker

$$\beta^{-1} \sim \sqrt{K\frac{dE}{dx}}$$

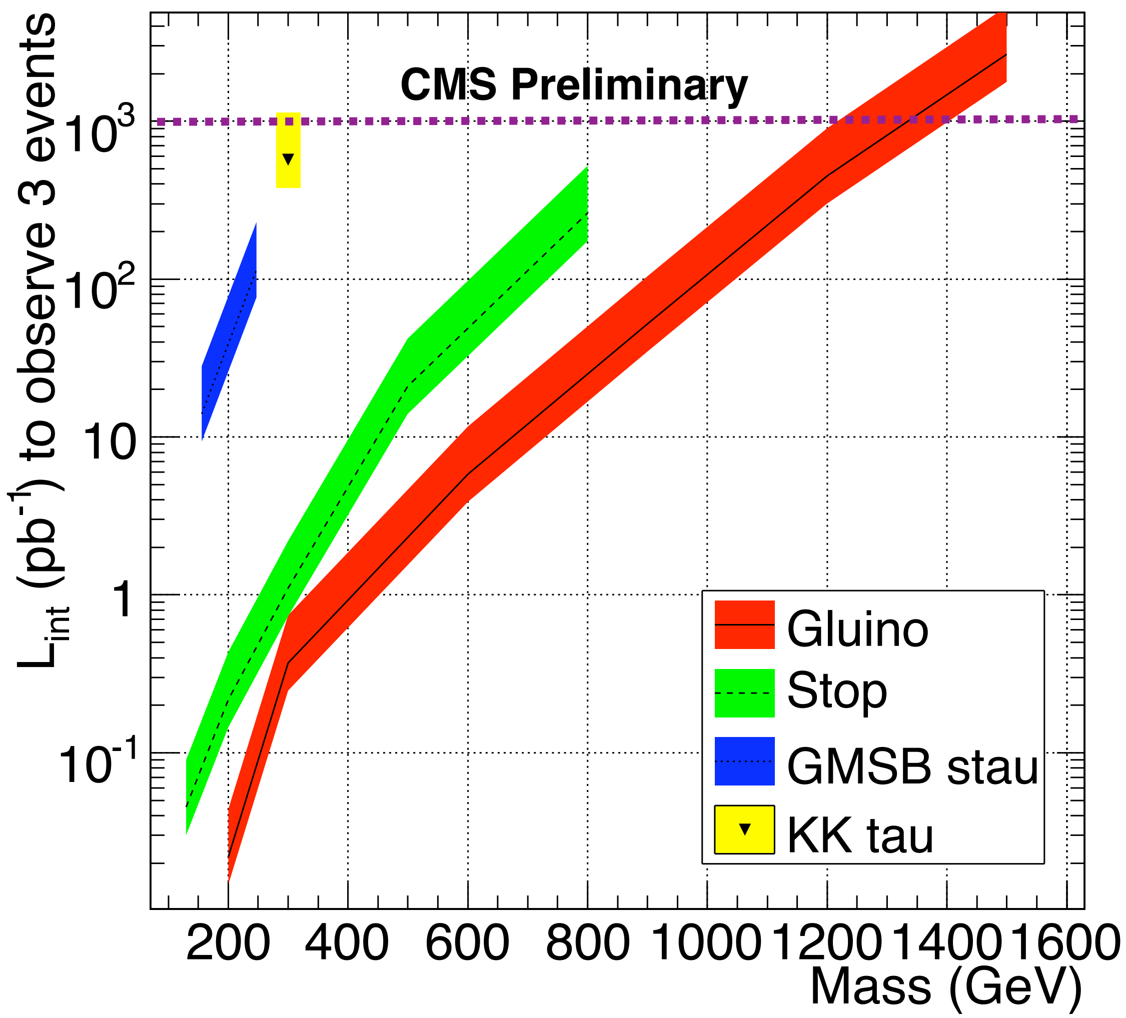
for β∈(0.1,0.8)





Discovery Potential

- CMS: TOF + dE/dx combined
  - $\beta_{TOF}<0.8$ + $\beta_{dE/dx}<0.8$ + track quality requirements
  - almost BG free ($N_{BG}<<1$ with 1 fb^{-1})
    - main BG: SM muons, cosmics
  - integrated luminosity to see 3 signal events:



CMS PAS EXO-08-003

Long lived charged particles can be observed with early data in a wide mass range

- GMSB stable $\tilde{\tau}$ can be discovered with O(100) pb^{-1}
- Sensitivity to stable gluinos above 1 TeV with 1 fb^{-1}

- ATLAS:

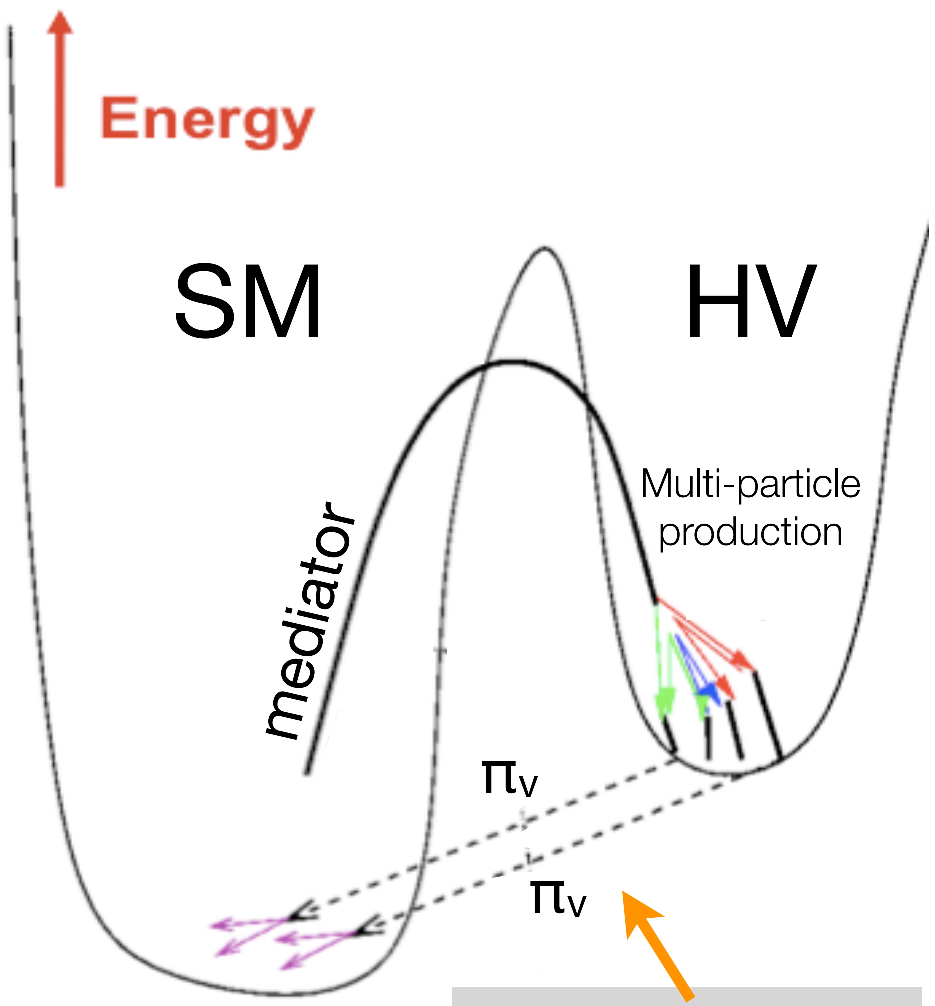
Sample	Mass [GeV]	Event Rate / fb^{-1}
$\tilde{g}$	300	6400
	600	2700
	1000	11
$\tilde{t}_1$	300	70
	600	4
BG	QCD di-jet	0.9
	$Z\rightarrow\mu\mu$	0.8

Preliminary not to be shown without approval from the ATLAS collaboration

Long Lived Neutral Particles decaying in Heavy Flavors

Benchmark model: Hidden Valley

M.Strassler and K.Zureck,: Phys.Lett.B 661:263 (2008)
Phys.Lett.B 651:374 (2007)



Slow decay back to SM sector

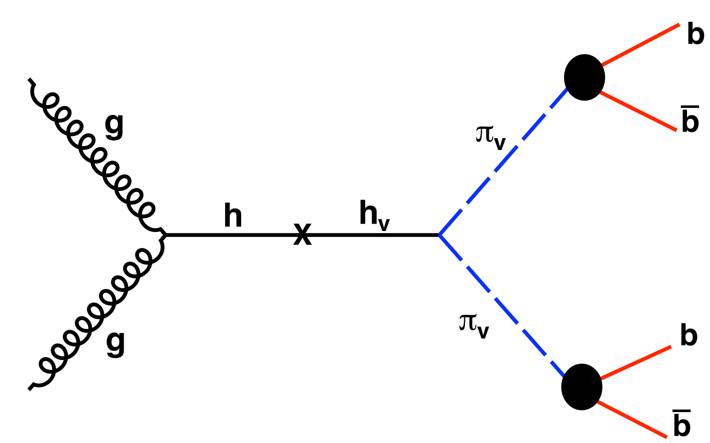
Hidden Valley models are a general class of models that predict neutral, long-lived particles

- Hidden Valley particles are SM-neutral, but some communication allowed via mediators (Higgs, Z´,LSP, ...)
- Lightest v-particles: π_v, stable in the hidden sector, can decay back to SM particles via mediator

Example:

$$h \rightarrow \pi_v \pi_v \rightarrow b\bar{b}b\bar{b}$$

$BR(\pi_v \rightarrow f\bar{f}) \propto m_f$



production can be as large as in SM

Long Lifetimes Expected
Highly displaced neutral vertices

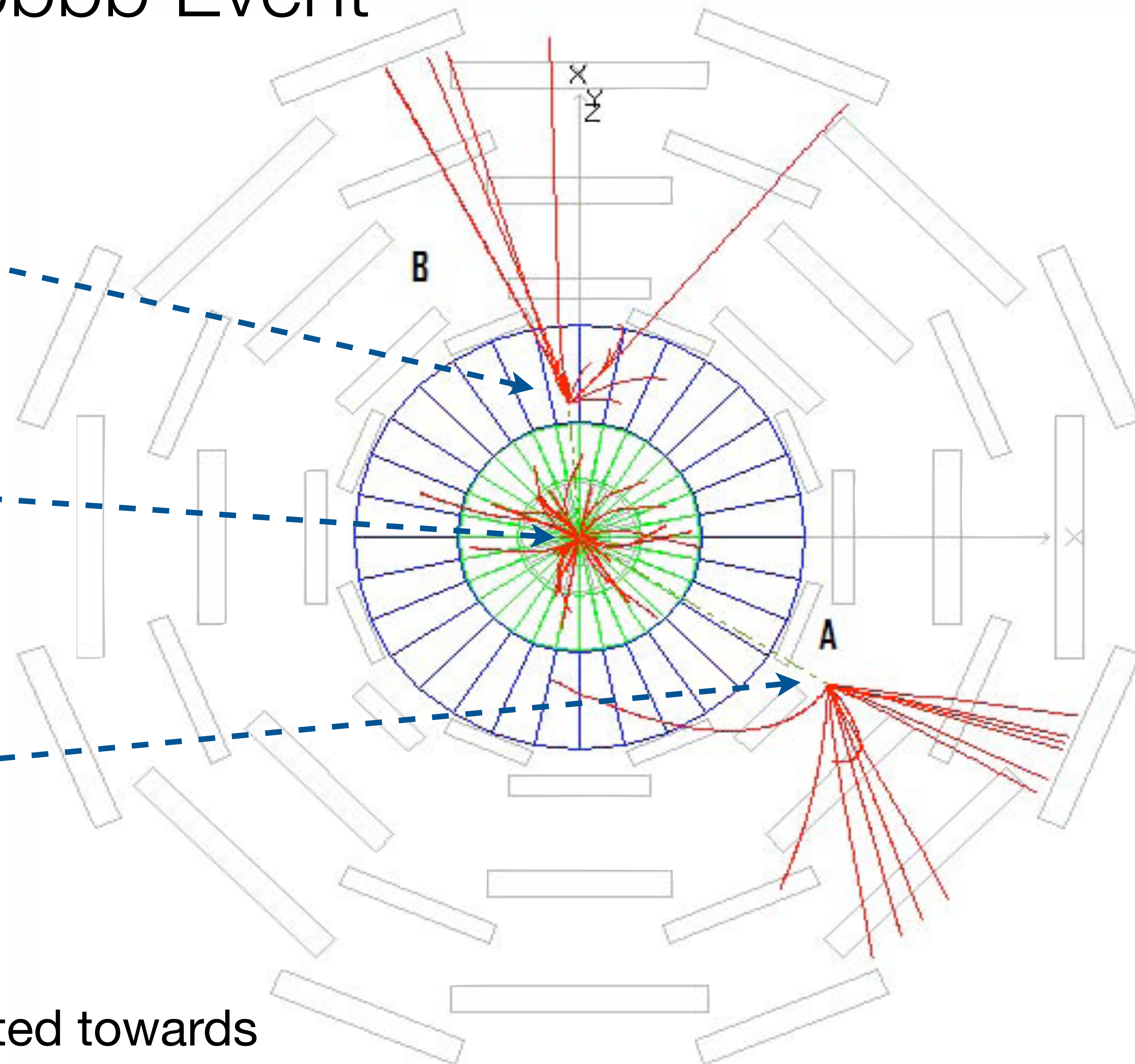
- unique topological signature
- HV processes almost background free → early discovery potential

A Typical $h \to \pi_v \pi_v \to b\bar{b}b\bar{b}$ Event

two b hadrons originating inside the hadron calorimeter

few low p_T tracks

two b-hadrons decaying inside the muon spectrometer

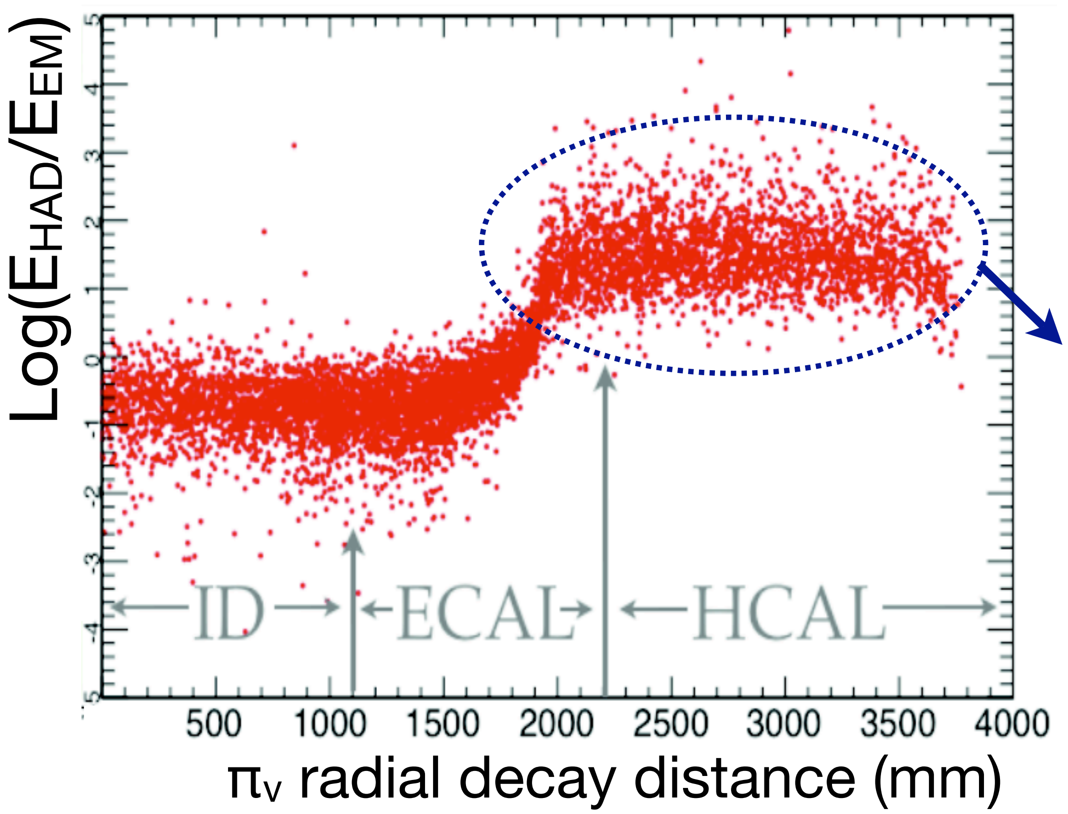


Trigger and reconstruction oriented towards objects coming from interaction point:

- example: matching with inner detector tracks for muons at Level-2

Solution: signature-driven triggers to select non IP connected events

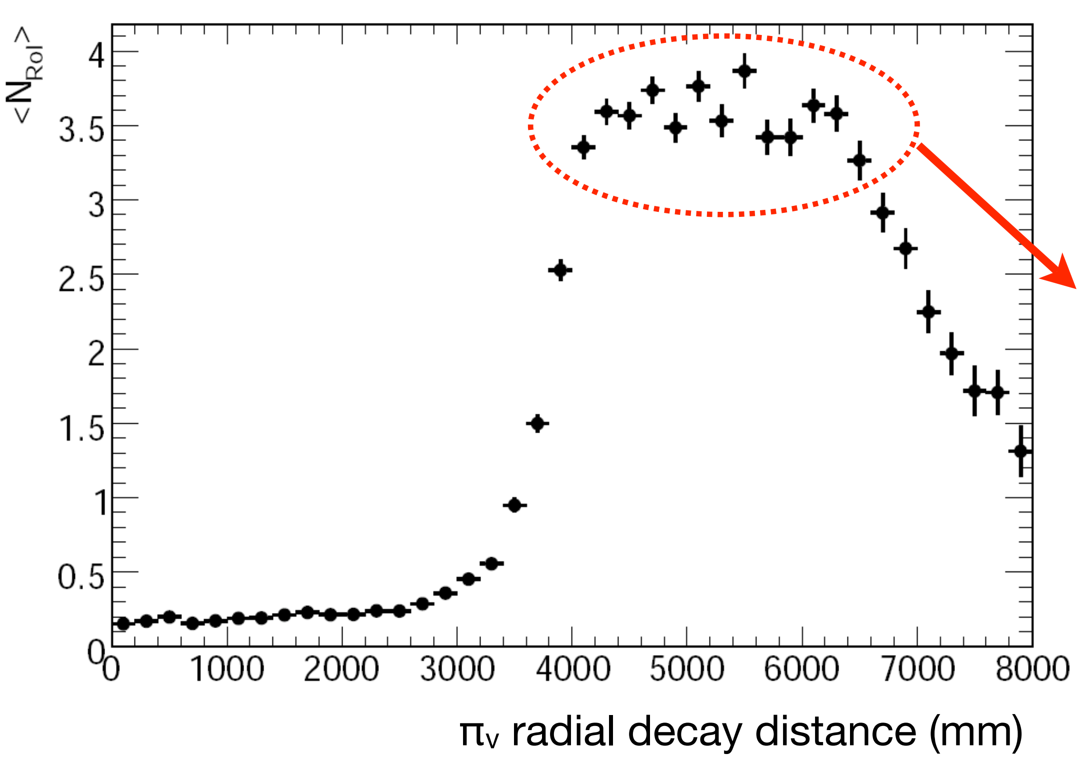
ATLAS Trigger Handles: Jets and Muons



Decays in or beyond Electromagnetic Calorimeter:

- E_{HAD}/E_{EM} ratio larger than observed for jets originating at IP
- Jets with no tracks associated in the Inner Detector

Level-1 Muon Candidates multiplicity



Decays near end of Hadron Cal. or in muon spectrometer:

- Clusters of tracks/segments in muon chambers in small ΔR regions
- No tracks in the Inner Detector
- No energy deposited in calorimeters

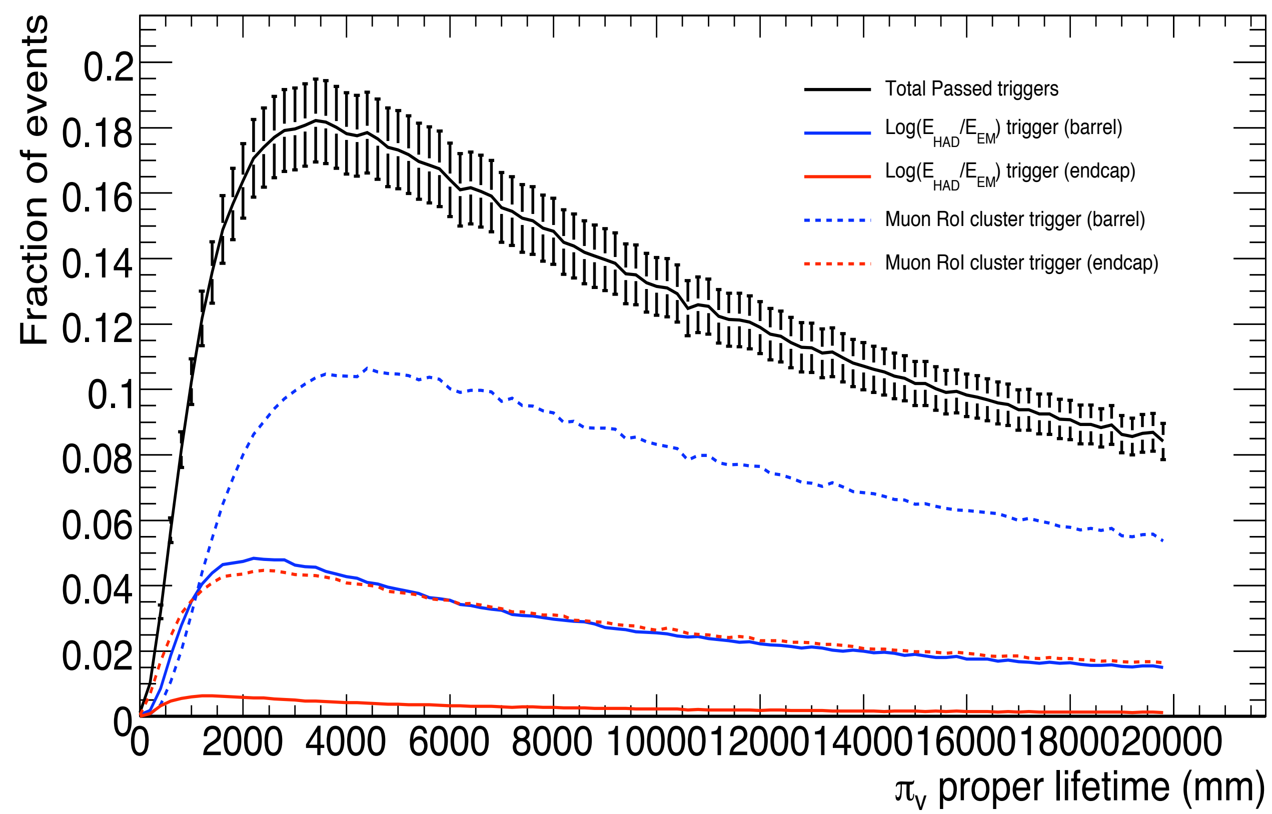
ATLAS Hidden Valley Triggers Performances

Three dedicated Level-2 triggers, fed with standard Level-1 Jet/Muon triggers:

- Trackless Jet with high Log(E_{HAD}/E_{EM}) Trigger
- Trackless Jet with an associated muon Trigger
- Muon Cluster Trigger

$h \rightarrow \pi_v \pi_v$	Level-1&Level-2 HV Triggers Efficiencies			
m_h=140 GeV $m_{\pi v}$=40 GeV $c\tau$=1.5 m	LogE_{HAD}/E_{EM}	Trackless Jet	Muon Cluster	Total
	5%	3.8%	9.0%	~16%

Trigger Efficiency VS π_v lifetime



Main background from QCD di-jets

Trigger rate @ L=10^{33} $cm^{-2}s^{-1}$ ~3 Hz

evaluated with minimum-bias and di-jet samples

good trigger efficiency in a wide π_v lifetime range at low background rate

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Conclusions

- Many extensions of the Standard Model predict “exotic” signatures that can be used as early discovery modes for BSM physics
- To succeed in this goal special attention in trigger and detector operation is crucial
- Still a lot of work on real data for both ATLAS and CMS to detect long lived particles, but Monte Carlo analyses suggest that clear signals can be observed with relatively low integrated luminosity, provided these particles are really present on the data ...

... very soon we’ll see